REMARKS

This application has been carefully reviewed in light of the Office Action dated August 12, 2002. Independent claims 8 and 42-44 have been amended. A marked-up version of these claims, showing changes made, is attached hereto as Appendix A. Claims 45-47 have been added. Claims 2-5, 8, 10-12, and 42-47 are now pending in this application. Applicants respectfully request reconsideration of the above-referenced application in light of the amendments and following remarks.

In the present Amendment, claim 8 has been amended to recite in pertinent part that the "steam [is] provided in a ratio of at least 0.005 relative to other gases present in the rapid thermal process chamber." Support for this recitation is found in Applicants' specification at page 8, lines 22-25.

Similarly, claims 42-43 have been amended to positively recite that the steam is provided "in a ratio of at least 0.005 relative to other gases present in the rapid thermal process chamber."

Independent claim 44 has been amended to positively recite the method of "subjecting the dielectric film to a wet oxidation with steam in a rapid thermal process chamber at a temperature of at least about 450°C and for a duration which increases the oxygen content of the dielectric film, said steam provided by a bubbled water vapor system in a ratio of at least 0.005 relative to other gases present in the rapid thermal process chamber."

Claim 44 stands rejected under 35 U.S.C. §112, second paragraph, as containing subject matter not described in the specification conveying to one skilled in the art that the Applicants had possession of the claimed invention.

At the outset, Applicants submit that independent claim 44 is supported by the specification (Applicants' specification, pages 7-8): Nonetheless, in response to the rejection, claim 44 has been amended to eliminate reference to mixtures of hydrogen and

oxygen gas. Accordingly, Applicants respectfully request that the § 112 rejection be withdrawn.

Claims 8, 2-5, and 10-12 stand rejected under 35 USC §103(a) as being unpatentable over Patel et al. (U.S. Patent No. 5,374,578) (hereinafter "Patel") in view of either Emesh et al. (U.S. Patent No. 5,728,603) (hereinafter "Emesh") or Chivukula et al. (U.S. Patent No. 6,066,581) (hereinafter "Chivukula"), and further in view of pages 157-160 of Van Zant, Microchip Fabrication, A Practical Guide to Semiconductor Processing, 3d Ed. McGraw-Hill (New York 1997) ("Van Zant"). Reconsideration is respectfully requested.

The claimed invention relates to a method of fabricating a semiconductor device in which an oxygen-deficient dielectric film is subjected to wet oxidation in a rapid thermal process chamber. As such, amended independent claim 8 recites a method of fabricating a semiconductor device by "depositing an oxygen-deficient dielectric film having a dielectric constant of at least about 25 over an underlying layer, subjecting the dielectric film to a wet oxidation with steam provided by heating a mixture of hydrogen and oxygen gases in a rapid thermal process chamber at a temperature of at least about 450 °C and for a duration which increases the oxygen content of the dielectric film, *said steam provided in a ratio of at least 0.005 relative to other gases* present in the rapid thermal process chamber, and subjecting the dielectric film to a heat treatment in an ambient comprising a stabilizing gas selected from the group consisting of N_2, O_2, O_3, NO, and N_2O" (emphasis added).

The Office Action asserts that the cited references render Applicants' invention obvious. Applicants respectfully disagree. Specifically, Applicants submit that there is no motivation to combine the cited references.

Patel discloses that "oxygen anneals are done in an O_2 ambient at a temperature greater than 500°C . . . using a furnace anneal or rapid thermal annealing process . . . [and] [u]nfortunately, the effect of these anneals can be reduced, or even eliminated, by some of the other processing steps used to form the ferroelectric capacitor." (Col. 1, lines 40-47)

(emphasis added). In particular, Patel suggests that "[o]zone anneals provide a more complete method of supplying oxygen . . . than oxygen anneals" (Col. 2, lines 11-13) (emphasis added). This is because "ozone . . . significantly decreases the number of lead (Pb) atoms lost during annealing as compared to using a conventional oxygen anneal in a furnace." (Col. 4, lines 18-22) (emphasis added). Accordingly, Patel uses an ambient atmosphere primarily comprising ozone. Patel also discloses that the anneal is conducted at a temperature in the range of about 650°C. to about 850°C. for about five to thirty seconds." (Col. 4, lines 11-15).

Conversely, Emesh teaches that when "annealing at 650°C., it is known that Ti from the adhesion layer, and Pb from PZT, may diffuse into the Pt layer . . . [and] may cause an increase in the leakage current." (Col. 2, lines 60-67). Further, that "a number of problems occur with integration of PZT and other ferroelectric materials into conventional process flows, many of these problems being related to the relatively high temperature which is required for processing." (Col. 3, lines 8-14) (emphasis added). Thus, the annealing process in Emesh is carried out at 450°C for 300 seconds (Col. 5, lines 19-45).

The Office Action asserts that Emesh teaches increasing the temperature at which the wet oxidation occurs increases the dielectric constant of the ferroelectric, and that this is support for the motivation to use higher temperatures than 500°C. However, Emesh specifically discloses that the focus of "this effort was a reduction of the crystallization temperature of the PZT from ~650°C. to <500°C." (Col. 5, lines 52-54) (emphasis added). There is no motivation to use temperatures higher than 500°C. Further, Patel teaches an anneal process at temperatures greater than 650°C. Thus, there is no motivation to combine Patel with Emesh.

Further, Emesh teaches that "annealing in higher ozone concentrations may be impractical for semiconductor processing, in view of safety concerns regarding toxicity and potential fire hazard of ozone at higher concentrations (>30% ozone), and the requirement that any unreacted ozone is destroyed before exhausting the annealing chamber to

atmosphere" (Col. 6, lines 9-15). Whereas, Patel teaches a "first anneal in an ozone atmosphere using a rapid thermal anneal process." (Col. 3, lines 64-65) (emphasis added). Emesh discloses that the anneal should only have a "few percent of ozone" (Abstract). This is an additional reason that these two references are not combinable.

Applicants also respectfully submit that the cited references, Patel and Chivukula, are not combinable as the Office Action asserts. Chivukula teaches using a "sol-gel precursor solution . . . using rapid thermal annealing at relatively low temperatures." (Col. 8, lines 22-25) (emphasis added). In fact, the ferroelectric layer is "annealed by a rapid thermal annealing (RTA) process at above 450°C., and up to 650°C." (Col. 13, lines 36-40) (emphasis added). "The combined effect of oxygen/ozone in the presence of water vapour was found to reduce significantly the temperature and time required for crystallization to occur, i.e., from above 650°C. . . . to about 450°C." (Col. 14, lines 34-38) (emphasis added). Conversely, Patel teaches that the "ozone molecule decomposes into an oxygen atom and oxygen molecule in a few milliseconds at 500°C. or above." (Col. 2, lines 25-27).

Accordingly, Patel benefits from using higher temperatures since ozone molecules will disassociate quickly; thus, increasing the diffusion of oxygen into the ferroelectric crystal and reducing the number of lead atoms that are lost, e.g., above 650°C, utilizing an ambient atmosphere primarily comprising ozone. Whereas, both Emesh and Chivukula are directed to low temperature anneals, e.g., below 650°C, in atmospheres with a very low percentage of ozone present. There is simply no suggestion or teaching that the methods of Emesh and Chivukula will work in an ambient atmosphere comprising primarily ozone, much less only ozone. Further, as is known in the art, utilizing bubbler systems requires the bubbler system to be opened to the atmosphere periodically to replenish the water. Even if the cited references were combinable as asserted, which they are not, the unreacted ozone of Patel would need to be first purged prior to adding water to the bubbler system. In contrast, both Chivukula and Emesh teach the addition of only a small percentage of ozone to the ambient atmosphere used in the annealing process.

The Office Action further relies on Van Zant for the proposition that Dryox rectifies the deficiencies associated with Emesh and Chivukula. Primarily, that Van Zant teaches using a mixture of hydrogen and oxygen to form steam rather than liquid systems such as a bubbler. However, Van Zant teaches that "under the influence of the high temperature," steam is formed (1st para., page 160) (emphasis added). Chivukula and Emesh are directed to low temperature anneals.

In addition, Van Zant teaches that "[b]ubblers . . . are adequate . . . [but] [l]iquid-water-steam systems are unreliable for growing thin, clean gate oxides." (Pages 159-160) (emphasis added). Further, a drawback to dryox system is the "explosive property of hydrogen." (Page 160). Accordingly, excess oxygen is flowed into the tubes to ensure that every hydrogen molecule will combine with an oxygen atom to form water (Page 160). Each of the cited references use ozone which already poses a potentially hazardous problem, particularly in Patel. Van Zant specifically discloses that at "oxidation temperatures, hydrogen is very explosive." (page 160) (emphasis added). There is no motivation to use the teachings of Van Zant with Emesh or Chivukula since the bubblers employed are adequate. Notwithstanding that neither of the cited references, Patel, Emesh, or Chivukula, discuss formation of a gate structure utilizing their methods. The dryox method is the preferred method only when talking about gate structures, even then, it is only a preferred method and not the only method.

Accordingly, even if the references were combinable as the Office Action asserts, the combination would fail to suggest the invention defined by independent claim 8. The combination fails to suggest a method of fabricating a semiconductor device by "depositing an oxygen-deficient dielectric film having a dielectric constant of at least about 25 over an underlying layer, subjecting the dielectric film to a wet oxidation with steam provided by heating a mixture of hydrogen and oxygen gases in a rapid thermal process chamber at a temperature of at least about 450 °C and for a duration which increases the oxygen content of the dielectric film, *said steam provided in a ratio of at least 0.005 relative to other gases* present in the rapid thermal process chamber, and subjecting the dielectric film to a heat

treatment in an ambient comprising a stabilizing gas selected from the group consisting of N_2, O_2, O_3, NO, and N_2O." (emphasis added).

Claims 2-5 and 10-12 depend from and include all of the limitations of independent claim 8 and are similarly allowable.

Claim 42 stands rejected under 35 USC §103(a) as being unpatentable over Patel et al. (U.S. Patent No. 5,374,578) (hereinafter "Patel") in view of either Emesh et al. (U.S. Patent No. 5,728,603) (hereinafter "Emesh") or Chivukula et al. (U.S. Patent No. 6,066,581) (hereinafter "Chivukula"), and further in view of Ohmi (U.S. Patent No. 5,840,368). Reconsideration is respectfully requested.

For at least the reasons provided above, the cited references Patel, Emesh, and Chivukula are not properly combinable. Ohmi adds nothing to rectify the deficiencies found in those cited references. Accordingly, it is respectfully requested that this objection be withdrawn.

In particular, the combination of cited references fail to suggest a method of fabricating a semiconductor device by "depositing an oxygen-deficient dielectric film having a dielectric constant of at least about 25 over an underlying layer, subjecting the dielectric film to a wet oxidation with steam provided by heating a mixture of hydrogen and oxygen gases in a rapid thermal process chamber at a temperature of at least about 450 °C and for a duration which increases the oxygen content of the dielectric film, said steam provided by a catalytic system *in a ratio of at least 0.005 relative to other gases* present in the rapid thermal process chamber, and subjecting the dielectric film to a heat treatment in an ambient comprising a stabilizing gas selected from the group consisting of N_2, O_2, O_3, NO, and N_2O." (emphasis added).

Claim 43 stands rejected under 35 USC §103(a) as being unpatentable over Patel et al. (U.S. Patent No. 5,374,578) (hereinafter "Patel") in view of the excerpt from Ghandi , VLSI Fabrication Principles, 2nd Ed., John Wiley & Sons (New York 1994), pgs.

465-466, and either of Emesh et al. (U.S. Patent No. 5,728,603) (hereinafter "Emesh") or Chivukula et al. (U.S. Patent No. 6,066,581). Reconsideration is respectfully requested.

For at least the reasons provided above, the cited references Patel, Emesh, and Chivukula are not properly combinable. Ghandi adds nothing to rectify the deficiencies found in those cited references. Accordingly, it is respectfully requested that this objection be withdrawn.

In particular, the combination of cited references fail to suggest a method of fabricating a semiconductor device by "depositing an oxygen-deficient dielectric film having a dielectric constant of at least about 25 over an underlying layer, subjecting the dielectric film to a wet oxidation with steam provided by heating a mixture of hydrogen and oxygen gases in a rapid thermal process chamber at a temperature of at least about 450 °C and for a duration which increases the oxygen content of the dielectric film, said steam provided by a pyrogenic system *in a ratio of at least 0.005 relative to other gases* present in the rapid thermal process chamber, and subjecting the dielectric film to a heat treatment in an ambient comprising a stabilizing gas selected from the group consisting of N_2, O_2, O_3, NO, and N_2O." (emphasis added).

Claim 44 stands rejected under 35 USC §103(a) as being unpatentable over Patel et al. (U.S. Patent No. 5,374,578) (hereinafter "Patel") in view of either Emesh et al. (U.S. Patent No. 5,728,603) (hereinafter "Emesh") or Chivukula et al. (U.S. Patent No. 6,066,581) (hereinafter "Chivukula"). Reconsideration is respectfully requested.

For at least the reasons provided above, the cited references Patel, Emesh, and Chivukula are not properly combinable. Accordingly, it is respectfully requested that this objection be withdrawn.

In particular, the combination of cited references fail to suggest a method of fabricating a semiconductor device by "depositing an oxygen-deficient dielectric film having a dielectric constant of at least about 25 over an underlying layer, subjecting the

dielectric film to a wet oxidation with steam in a rapid thermal process chamber at a temperature of at least about 450 °C and for a duration which increases the oxygen content of the dielectric film, said steam provided by a bubbled water vapor system *in a ratio of at least 0.005 relative to other gases* present in the rapid thermal process chamber, and subjecting the dielectric film to a heat treatment in an ambient comprising a stabilizing gas selected from the group consisting of N_2, O_2, O_3, NO, and N_2O." (emphasis added).

New claims 45-47 have been added to round out the scope of protection afforded by the invention. The cited references fail to teach or suggest the subject matter of claim 45 which recites a method of fabricating a semiconductor device by *inter alia*, "subjecting the dielectric film to a wet oxidation anneal process consisting of steam provided by heating a mixture of hydrogen and oxygen gases in a rapid thermal process chamber at a temperature of at least about 450 °C and for a duration which increases the oxygen content of the dielectric film." (emphasis added).

The cited references also fail to teach or suggest the subject matter of claim 46 which recites a method of fabricating a semiconductor device by *inter alia*, "subjecting the dielectric film to a wet oxidation anneal process with steam provided by heating a mixture of hydrogen and oxygen gases in a rapid thermal process chamber at a temperature of at least about 450 °C and for a duration which increases the oxygen content of the dielectric film, said steam provided in a ratio of about 0.1 to about 0.5 relative to other gases present in the rapid thermal process chamber." (emphasis added).

Further, the cited references fail to teach or suggest the subject matter of claim 47 which recites a method of fabricating a semiconductor device by *inter alia*, "subjecting the dielectric film to a wet oxidation anneal process with steam provided by heating a mixture of hydrogen and oxygen gases in a rapid thermal process chamber at a temperature of at least about 450 °C and for a duration which increases the oxygen content of the dielectric film, said wet oxidation anneal process comprising only of hydrogen and oxygen gases, wherein the ratio of hydrogen to oxygen gases in the mixture is in the range of about 0.1 to about 0.8." (emphasis added).

In summary, for all of the reasons set forth above, the cited references, whether considered alone or in combination, fail to disclose or suggest the above-mentioned features of the claimed invention. Allowance of the application with claims 2-5, 8, 10-12, and 42-47 is respectfully solicited.

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Respectfully submitted,

By_________________________

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APPENDIX A

8. (five times amended) A method of fabricating a semiconductor device comprising:

depositing an oxygen-deficient dielectric film having a dielectric constant of at least about 25 over an underlying layer;

subjecting the dielectric film to a wet oxidation with steam provided by heating a mixture of hydrogen and oxygen gases in a rapid thermal process chamber at a temperature of at least about 450 °C and for a duration which increases the oxygen content of the dielectric film, <u>said steam provided in a ratio of at least 0.005 relative to other gases present in the rapid thermal process chamber</u>, wherein the ratio of hydrogen to oxygen gases in the mixture is in the range of about 0.1 to about 0.8; and

subjecting the dielectric film to a heat treatment in an ambient comprising a stabilizing gas selected from the group consisting of N_2, O_2, O_3, NO, and N_2O.

42. (amended) A method of fabricating a semiconductor device comprising:

depositing an oxygen-deficient dielectric film having a dielectric constant of at least about 25 over an underlying layer;

subjecting the dielectric film to a wet oxidation with steam provided by heating a mixture of hydrogen and oxygen gases in a rapid thermal process chamber at a temperature of at least about 450 °C and for a duration which increases the oxygen content of the dielectric film, [the] <u>said</u> steam [being] provided by a catalytic system <u>in a ratio of at least 0.005 relative to other gases present in the rapid thermal process chamber</u>; and

subjecting the dielectric film to a heat treatment in an ambient comprising a stabilizing gas selected from the group consisting of N_2, O_2, O_3, NO, and N_2O.

43. (amended) A method of fabricating a semiconductor device comprising:

depositing an oxygen-deficient dielectric film having a dielectric constant of at least about 25 over an underlying layer;

subjecting the dielectric film to a wet oxidation with steam provided by heating a mixture of hydrogen and oxygen gases in a rapid thermal process chamber at a temperature of at least about 450 °C and for a duration which increases the oxygen content of the dielectric film, [the] <u>said</u> steam [being] provided by a pyrogenic system <u>in a ratio of at least 0.005 relative to other gases present in the rapid thermal process chamber</u>; and

subjecting the dielectric film to a heat treatment in an ambient comprising a stabilizing gas selected from the group consisting of N_2, O_2, O_3, NO, and N_2O.

44. (amended) A method of fabricating a semiconductor device comprising:

depositing an oxygen-deficient dielectric film having a dielectric constant of at least about 25 over an underlying layer;

subjecting the dielectric film to a wet oxidation with steam [provided by heating a mixture of hydrogen and oxygen gases] in a rapid thermal process chamber at a temperature of at least about 450 °C and for a duration which increases the oxygen content of the dielectric film, [the] <u>said</u> steam [being] provided by a bubbled water vapor system <u>in a ratio of at least 0.005 relative to other gases present in the rapid thermal process chamber</u>; and

subjecting the dielectric film to a heat treatment in an ambient comprising a stabilizing gas selected from the group consisting of N_2, O_2, O_3, NO, and N_2O.